

# **Improvements to Tropical Cyclone Model Forecasts**

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## **LONG-TERM GOALS**

The long-term goal is to investigate, develop, and implement the ability to analyze and predict the tropical cyclone structure and intensity, and to further improve the prediction of the tropical cyclone track through the use of numerical prediction systems and satellite observations.

## **OBJECTIVES**

The objective is to improve the initial analysis of 3-dimensional tropical cyclone structure by the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), and study how the improved structure analysis leads to further improvements in tropical cyclone track, structure, and intensity forecasts. Special emphasis will be placed on including the asymmetric structure of tropical cyclones in the analysis.

## **APPROACH**

Our approach is to develop a method to initialize tropical cyclone structure in high resolution ( $< 10$  km grid spacing) applications of COAMPS. This method will use the NRL Atmospheric Variational Data Assimilation System (NAVDAS) to analyze the tropical cyclone structure by using a combination of all available real-time observations, and analytic models of idealized tropical cyclone structure. Since few, if any, observations are typically available to describe the tropical cyclone structure, an idealized 3-dimensional wind structure for tropical cyclones is generated using remotely-sensed and, if available, in-situ observations. Individual profiles (i.e., synthetic observations) are then retrieved in concentric circles surrounding this idealized structure. Such a procedure for generating synthetic observations is currently being used in the Navy Operational Global Atmospheric Prediction System (NOGAPS). The horizontal spacing between the concentric circles of these synthetic observations is approximately 200 km. The current version of COAMPS run at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) also uses these coarse-resolution synthetic observations. In general, this procedure makes the tropical cyclone circulation in the COAMPS analysis too large and too smooth. Furthermore, these synthetic observations do not include any asymmetries that are often present in tropical cyclone circulations. In this project, we will improve the ability to construct synthetic observations for tropical cyclones, specifically for high-resolution applications of COAMPS. The new initialization system will be capable of generating high-resolution synthetic observations that contain information about the maximum wind; the radius of the maximum wind, the 50 knot wind, and the 35 knot wind; the surrounding environmental flow; and asymmetries of individual tropical cyclones. It is hypothesized that the analysis of the tropical cyclone structure resulting from the use of these

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observations, along with related efforts to improve COAMPS physical parameterizations, will lead to improvements in the prediction of tropical cyclone track, structure, and intensity by COAMPS. A comprehensive set of validation tests will be performed to test this hypothesis. As part of our evaluation, we will pay special attention to those cases that had large forecast track errors.

## **WORK COMPLETED**

A prototype tropical cyclone initialization system that is patterned after the operational tropical cyclone initialization system currently used in NOGAPS, has been developed for COAMPS. The major improvements in the new system for COAMPS include: (a) increased horizontal and vertical resolution of the synthetic observations, (b) inclusion of the asymmetric structure of tropical cyclones in the synthetic observations, (c) improvement in the gradient-balanced height calculation by considering the environmental mean wind, and (d) determination of the environmental flow of a tropical cyclone by considering its size. For each tropical cyclone, the cyclone structure is represented by 41 synthetic observations, rather than the 13 used currently. An idealized tropical cyclone circulation is computed from a tropical cyclone structure model that uses observed maximum wind speed and radii of 35- and 50-knot wind available in warning messages issued by the Joint Typhoon Warning Center (JTWC) as input data. The tropical cyclone circulation is computed separately in each of 4 quadrants so that asymmetric structure will be included in the tropical cyclone circulation if the JTWC warning messages indicate so. The surrounding environmental flow is computed from the NOGAPS analysis, after it has been smoothed to remove the circulation associated with the tropical cyclone circulation. The degree of smoothing depends upon the average 35-knot wind radius of each tropical cyclone.

Case studies have been conducted to test and evaluate the new tropical cyclone initialization system for the COAMPS. We selected two western Pacific tropical cyclones from 8 September 2000 for detailed evaluation (wp22 and wp24). The cyclone wp22 was a large (i.e., 35 knot wind radius of 350 km) and strong storm (i.e., maximum wind speed of 90 knots), while the cyclone wp24 was a small (i.e., 35 knot wind radius of 130 km) and weak (i.e., maximum wind speed of 50 knots). The comparison of the tropical cyclone structure initialized by the operational and new initialization systems indicates that the new system significantly improved the tropical cyclone structure both in the COAMPS analysis and forecast. The tropical cyclone tracks were also better predicted in the version of COAMPS that used the new initialization system based on results from 29 test runs.

## **RESULTS**

Synthetic observations generated by the operational and new tropical cyclone initialization systems were compared for cyclone wp22 (not shown) and cyclone wp24 (Fig. 1). In both cases, synthetic observations generated by the new system show stronger inner circulation and weaker outer circulation as compared with those generated by the operational method. A triply-nested COAMPS, with grid spacings of 45, 15, and 5km, was initialized using the new synthetic observations together with other observations to produce a 48h forecast. The wind analysis using the new set of synthetic observations displayed much stronger and tighter tropical cyclone circulation than that using the operational synthetic observations for both 15 km (Fig. 2) and 5 km resolutions (not shown). The tighter cyclone circulation from the new initialization system may be responsible for a better simulation on the interaction between cyclones wp22 and wp24 that led to a better COAMPS 48h track forecast (Fig. 3). To prepare for the transition of this new analysis technology to FNMOC, two sets of 29 forecasts of tropical cyclones for the western Pacific were made using COAMPS with a doubly-nested grid (81/27

km). One set of forecasts used the current operational coarse-resolution synthetic observations, while the other set of forecasts used the new high-resolution synthetic observations to initialize the tropical cyclone structure for each forecast. The results from these tests indicate that the new tropical cyclone initialization system reduced the track error forecasts by approximately 10% (Fig. 4).

## IMPACT/APPLICATIONS

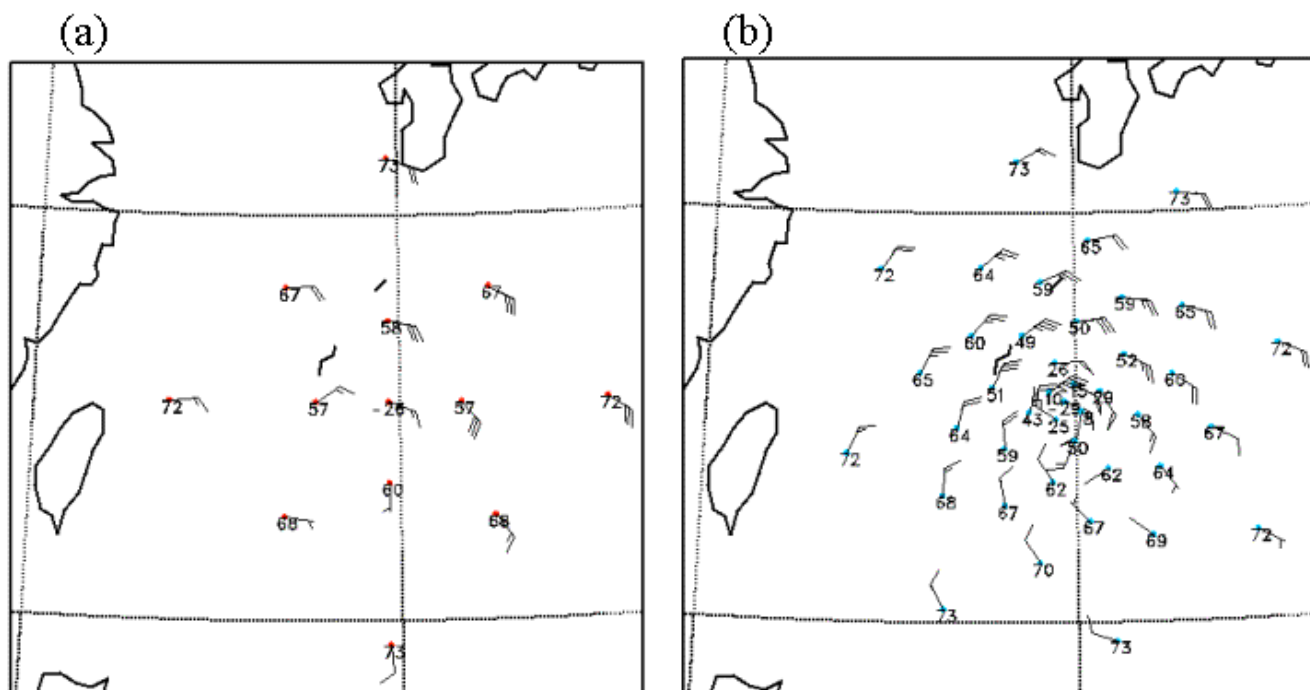
The tropical cyclone initialization system developed improves the COAMPS analysis in tropical cyclone structure and preliminary tests indicate improvements to tropical cyclone forecast structure and track. Such improvements will lead to cost savings for the Navy from more accurate decisions on warnings and sorties in the event of tropical cyclones.

## TRANSITIONS

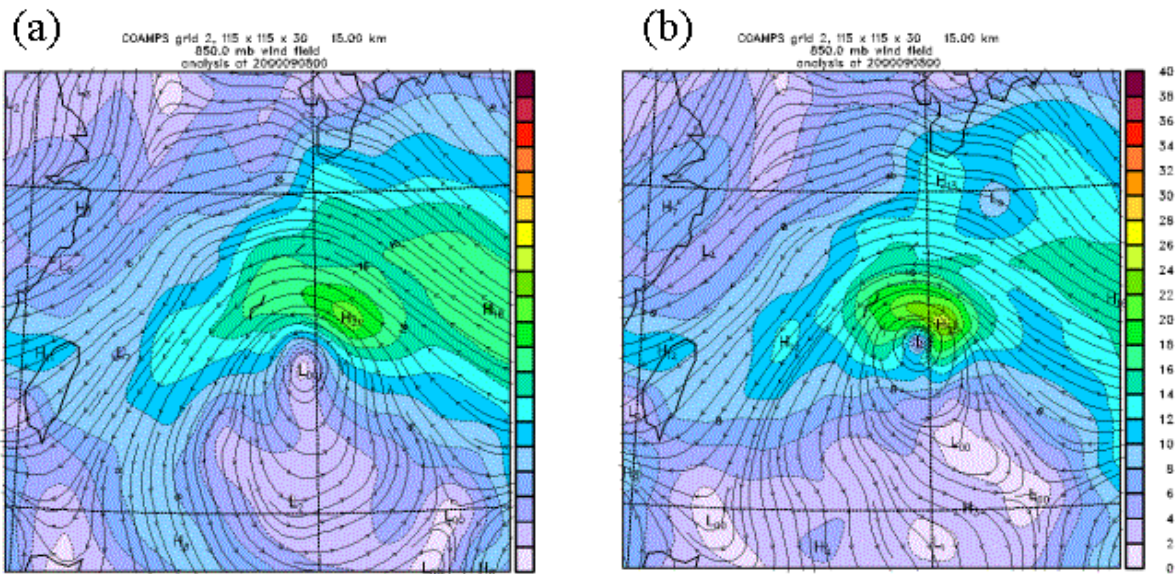
We are working with FNMOC to further test and evaluate the tropical cyclone initialization system developed for COAMPS and to get ready for operational installation.

## RELATED PROJECTS

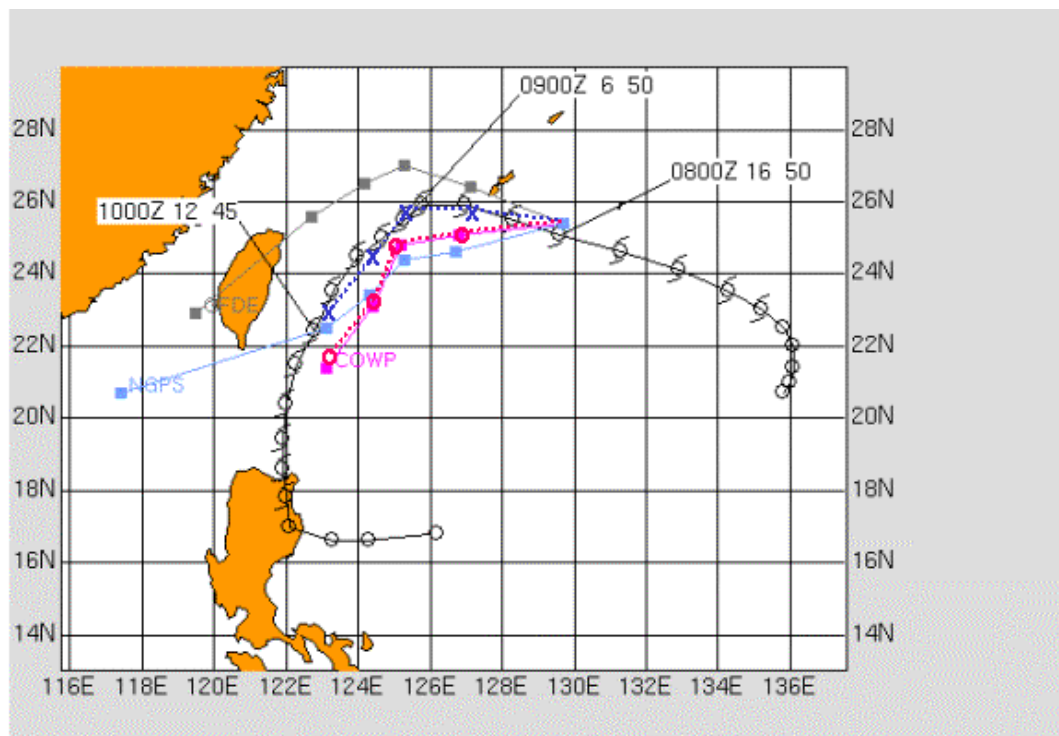
Related 6.2 projects within PE 0602435N are 3532, for the *High Resolution Mesoscale Model Prediction and Validation*, and BE-35-2-32, for the *Satellite/NWP Data Fusion for Weather Assessment*; and a related 6.4 project under PE 0603207N is X-2342 for the *Tropical Cyclone Forecast Systems*.



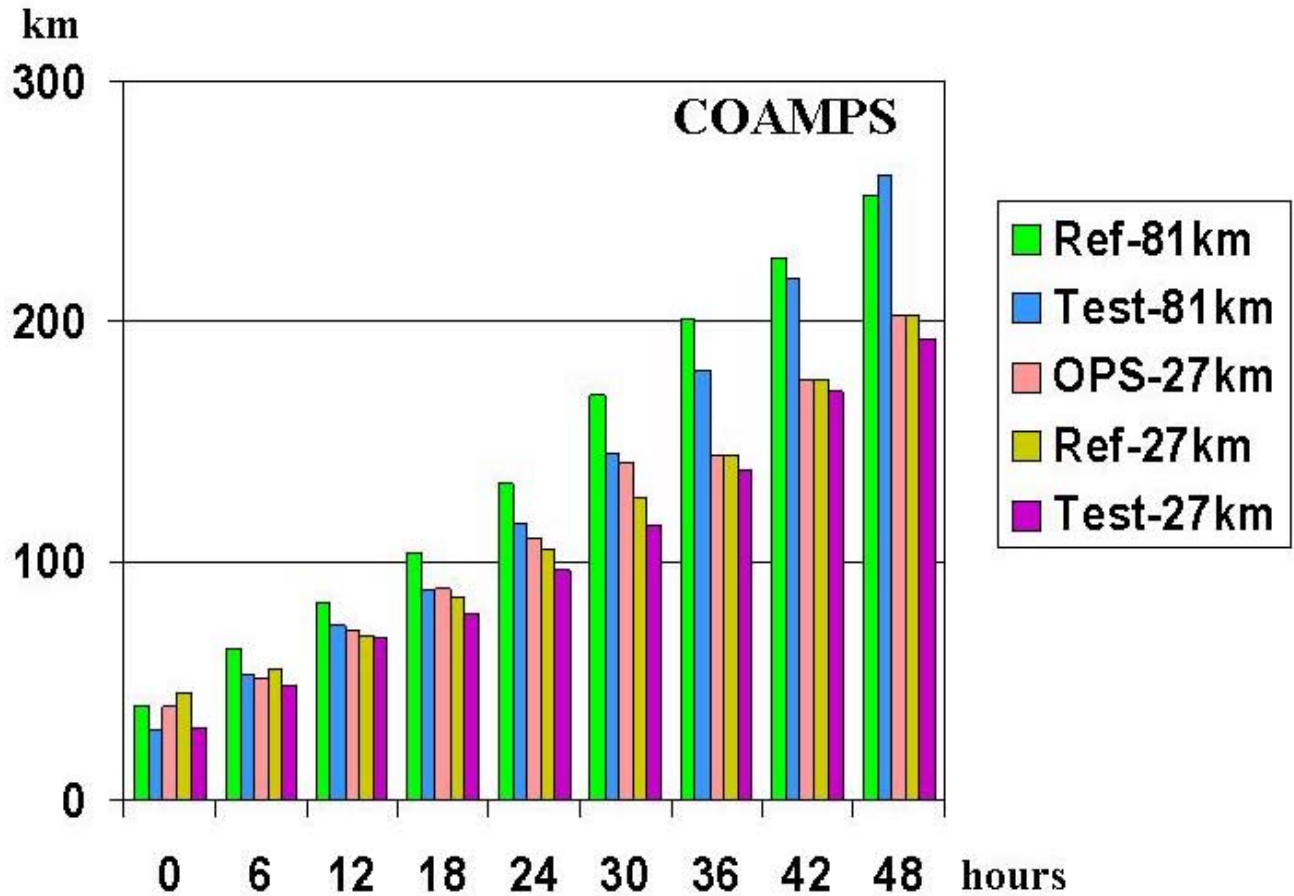
**Figure 1. Comparison of synthetic observations at 1000 mb generated by (a) operational and (b) new initialization system for tropical cyclone wp24 at 0000 UTC 8 September 2000. Numbers are for height values and wind bars are in units of 10 knots.**



**Figure 2. Comparison of analyzed 850 mb wind with synthetic observations from (a) operational and (b) new tropical cyclone initialization system. The colored contours show wind speed in m/s.**



**Figure 3. Track forecast of cyclone wp24 from 0000 UTC 8 September 2000 by COAMPS initialized with synthetic observations from the operational (dashed O) and new initialization (dashed x) systems, and by operational forecasts of COAMPS (COWP), NOGAPS (NGPS), and GFDE (GFDE). Best track positions are marked by the storm symbols in every 6 hours, and forecast track positions are marked at tau=0, 12, 24, 36, 48 and 72 hours.**



*Figure 4. Error statistics of tropical cyclone track forecast from 29 COAMPS forecasts initialized with synthetic observations generated by operational (green for coarse and yellow for inner meshes) and new (blue for coarse and purple for inner meshes) initialization systems, and operational COAMPS forecast of inner mesh (pink).*